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THE CRITICAL PERIOD OF ARVENSES COMPETITION WITH THE CROP OF CORN (*Zea mays* L.) IN HUAMBO, ANGOLA

Período crítico de competencia de las arvenses con el cultivo de maíz (*Zea mays* L.) en Huambo, Angola

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ABSTRACT. The investigation was directed to the determination of the critical period of competition among the weeds and the corn (*Zea mays* L.), a crop of economic interest and main food of the nutritious diet of the population of the county of Huambo. The sowing of two experiments was carried out on a Ferralitic soil with a variety of long cycle, in an agricultural ecosystem severely affected by the limitless use of herbicides, what has generated very aggressive, dominant species and the difficult handling. A design of blocks settled down at random, with eighteen treatments and four replication for two circumstance "with weed until" and "without weed until" at the 7, 14, 21, 28, 35, 42, 49, 56 days after the germination and a control with and without weed the whole cycle of the cultivation of corn, for each circumstance respectively and in a later experiment, just by three treatments (with and without weed during the whole cycle and without weed only in the critical opposing period). Among the dominant species they were: *Cyperus rotundus* L., *Bidens pilosa* L., *Cynodon dactylon* (L.) Pers. and *Chloris polydatyla* (L.) Swartz. the results showed that the critical period of competition of the weed with the corn crop is located between 21 to 49 days to the germination, imperative moment to carry out works of weed handling. Before and after this period, doesn't benefit to the crop and the production costs were increased. The relationship between the height and number of leaf of the plant with the yield and number of days with and without weed, showed positive for R^2 superior to 0,95 for both variable *vs* yields and similar answer regarding the days "with and without weed until", but with better adjustment.

Key words: crop, corn, interspecific competition, agroecosystem

RESUMEN. La investigación estuvo dirigida a la determinación del periodo crítico de competencia entre las arvenses y el maíz (*Zea mays* L.). Se sembraron dos experimentos sobre un suelo Ferralítico con una variedad de ciclo largo, en un agroecosistema severamente afectado por el uso desmedido de herbicidas. Se estableció un diseño de bloques al azar, con dieciocho tratamientos y cuatro replicas para dos circunstancias "con arvenses hasta" y "sin arvenses hasta" a los 7, 14, 21, 28, 35, 42, 49, 56 días después de la germinación y un testigo, con y sin arvenses todo el ciclo, para cada circunstancia respectivamente y en un experimento posterior, con sólo tres tratamientos (con y sin arvenses durante todo el ciclo y sin arvenses solo en el período crítico encontrado). Entre las especies dominantes se encontraron: *Cyperus rotundus* L., *Bidens pilosa* L., *Cynodon dactylon* (L.) Pers. y *Chloris polydatyla* (L.) Swartz. Los resultados mostraron que el período crítico de competencia entre las arvenses y el maíz se ubica entre 21 y 49 días posterior a la germinación, momento imperativo para realizar labores de manejo de arvenses. Antes y después de este período, no beneficia al cultivo y se incrementan los costos de producción. La relación entre la altura y el número de hoja de la planta con el rendimiento y el número de días con y sin arvenses, fue positiva para R^2 superior a 0,95 para ambas variables *vs* rendimiento y similar respuesta respecto a los días "con y sin arvenses", con mejor ajuste para la primera.

Palabras clave: crecimiento, maíz, competencia interespecífica, agroecosistemas

INTRODUCTION

Since the last decade of the XX century and based on agroecological principles, a new way of looking at the interspecific competition and contrary to the concept of the known "weeds", the term "weed" or plants growing on crops, was coined (1);

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then, weeds are equilibrating and reservoir species of the productive diversity in agroecosystems, since they are hosts of the beneficial fauna of productive environments (2).

Even when weeds are still an enigma of Nature, loaded of mysteries and probable benefits for mankind, they are also plants that under interspecific competition, limit yields of economic crops (3). Therefore, the sucess of managing a productive system lies on reducing weed populations during the critical development period of the crop and keep them below the economic damage threshold disregarding the concept of "totally clean field" by using herbicides" suported by the principles of the so-called Modern Agriculture[A].

As in the rest of the world, the negative effects of herbicides have invaded corn fields in Huambo, Angola, with the establishment of species like *Cyperus rotundus* L.*,* whose management with chemicals is something that cannot be put off; therefore, finding new management alternatives is a must that demands knowing the period in which weeds affect yields, that is, determining the critical period of competition weeds *vs* corn.

MATERIALS AND METHODS

This research started in October 2011 at the Experimental Farm of the Agricultural Science Faculty (FCA) of Huambo, "José Eduardo dos Santos" University (UJES), in Ngongoinga, Huambo province, on a Ferralitic soil of clayish-sandy deep clay texture with good drainage though poor in organic matter and nutrients[B] (4).

The studied treatments match the approach leading to find the critical point of weeds-crop interspecific competion, an strategy of ascending of effects and damages (*without weed management till)* and descending (*with weed management till)* as shown in Table I. This information has been used by several authors to study critical periods (5, 6).

A total of 18 treatments under a random block design with four replicates were true for each of the strategic approaches, reaching a total of 72 plots. Weeds were cut every seven days so the interspecific competition time between treatments was always the same. The variety used was SAM3 of long cycle (six months) and the other cultural practices like: soil preparation, planting and other labors during crop cycle were done according to the technical guidelines for the crop under Huambo's conditions and adapted to the technical standards for corn[C].

Prior to corn planting, observations on the weed composition were done, its yields are expressed in t ha^{-1}. A total of 45 plants per plot were found, the relationship between plant height and the number of days with and without weeds was determined by a third degree polynomial equation. Observations every seven days were made, using a frame of 1 m^2 repeated three times in each plot to determine the number of weed species per treatment.

A second trial on less exploited soil was conducted, with the same variety and the same objectives on October 2013 at the Agronomical Research Institute in Chianga, 20 km away from the first trial. This second trial looked at confirming the results of the first one regarding the critical period found, for which only three treatments with four replicates were used.

Table I. Treatments included in the experiment of critical period

Treatments	Treatments
With weed management "till"	Without weed management "till"
7 days after weed emergence	**7 days after weed emergence**
14 days after weed emergence	14 days after weed emergence
21 days after weed emergence	21 days after weed emergence
28 days after weed emergence	28 days after weed emergence
35 days after weed emergence	35 days after weed emergence
42 days after weed emergence	42 days after weed emergence
49 days after weed emergence	49 days after weed emergence
56 days after weed emergence	56 days after weed emergence
Throughout the crop cycle	Throughout the crop cycle

[A] Leyva, G.A.; Oria, M.J.R. y Bertoli, M. ''Efecto de las adventicias en las plantaciones de caña de azúcar en la zona occidental de Cuba'', *XVIII Congreso de la ISSCT*, La Habana, Cuba, 1982.

[B] Instituto de Investigación Agronómica. *Instructivo técnico para cultivos locales en Huambo*, Angola, 2011, pp. 9-13.

[C] Empresa de Proyecto e Ingeniería de Guantánamo. *Programa de desarrollo Agropecuario Integral del municipio El Salvador*, [224], Ministerio de la Agricultura, Guantánamo, Cuba, 2011, 30 p.

- Corn without weed management throughout the cycle.
- Corn with weed management only in the determined critical period.
- Corn without weeds throughout the cycle (totally clean field)

Experimental conditions and the rest of cultural practices applied in this second trial followed the same technical standards of the first one using the same data and observations.

The results were checked from yields per plot and expressed in t ha^{-1}. Harvest was made six months after planting by weighing all dry cobs per treatment.

Data were processed with the software package *Statistical Package for the Social Sciences* - SPSS (7) as a tool for statistical analysis to determine the differences among means by Duncan's multiple range test.

RESULTS AND DISCUSSION

Weeds and its predominance in Nongoinga and Chianga

In both locations, a total of 98 species were found, out of them, 42 in Ngongoinga and 56 in Chianga. Among predominant species in Ngongoinga were: *Cyperus rotundus* L. (Longuenso o Tchinguesso), *Bidens pilosa* L. (Olokoso) *Cynodon dactylon* (L.) *Pers. (*Ndogoloca) and *Chloris polydatyla* (L.) *Swartz* (Ulungumbe). The least frequent species were: *Phyllanthus tenellus* Roxb**.** (commonly known as Usese) it is used as herb for tooth aches, back aches and to facilitate dilation at birth; and *Solanum americanum* Mill (known as lossuya), its leaves are used for human food; the stem is good for typhoid fever and massage, while its fruits are used to feed chicken.

Other weeds emerge as subordinated species and do not play a determinant role in the agroecosystem, since the mentioned ones are the predominant species, particularly *Cyperus rotundus* L. (Longuenso or Tchinguesso), which is nearly unique within corn plots (Photo 1).

The Chianga location is a site where the non-sequential crop rotation is practiced so there are not permanent predominant species.

The specie *B. pilosa* L. (Olokoso), is one of the most frequent one, apart from being a docile specie, it plays an important role for the community because its leaves are useful for human feeding.

Predominance of *Cyperus rotundus* L. for the excessive use of herbicides

Also found were: *Cynodon dactylon* (L.) *Pers. (*Ndogoloca) and *Comelina diffusa* Burn. (Essolo), *Richardia brasiliensis* Gomes (Calongupa) as well as *Acanthosperm umhispidum* DC. (Tchanbanda), *Eleusine indica* L. Gaertn. (Ulungumbe) *Amaranthus deflexus* L. (Gimboa) and *Argemone mexicana* L.

Despite the short distance separating both locations, the marked differences between both of them, seem to be related with the excessive use of herbicides of the simetric triazine group and those derived from urea, for more than 30 years in Ngongoinga. Such herbicides, in spite of being recommended for corn, are not effective against *C. rotundus* L.[D]. This specie gets hold of the agricultural space in productive systems and are the main obstacle in terms of interspecific competition for this location.

Although it is true that competition in early stages are not reversible and non-recoverable (8). Some authors state that weeds can increase the organic matter content and create a favorable environment for the micro and macroflora[E]. Other authors state that when weeds live under interspecific competition with corn, yields are seriously damaged (9); but at the same time they make emphasis that such weeds are vital to solve erosion, cover and fertility conservation problems increasing the total stability of agricultural systems, and also beneficial insects. Therefore, combined management practices are recommended to achieve a more efficient control with less herbicides (10, 11). The key is to live together with weeds wihout economic damages to the crop.

[D] Sarandón, S. J. ''Biodiversidad, agrobiodiversidad y agricultura sustentable: Análisis del Convenio sobre Diversidad Biológica'', *Vertientes del pensamiento agroecológico: fundamentos y aplicaciones, IDEAS*, vol. 21, 2010, pp. 105–130.

[E] Cirujeda, A.; Zaragoza, C. y Aibar, J. ''Factores que influyen en la biodiversidad de la flora arvense de los cereales'' [en línea], En: *VIII Congreso SEAE Bullas*, Murcia, España, 2008, [Consultado: 1 de julio de 2015], Disponible en: <http://www.agroecologia.net/recursos/publicaciones/publicaciones-online/2009/eventos-seae/cds/congresos/actas-bullas/seae_bullas/verd/sesiones/12%20S3C.%20SANIDAD%20(II)/S3C1.pdf>.

Results of the critical competition period between weeds and corn. Plant height and number of leaves. Relationship between the days with and without management

The analysis of results started with the relationship between corn growth variables *vs* days with and without weed management, shown in Figure 1; also relating plant growth, plant height and number of leaves with management approaches "with weeds till" and "without weeds till…! (Figure 1 A and B;

Based on the results of the analysis, the relationship between plant height and the number of days with and without weeds was determined. The highest value for the third degree polynomial equation was an R^2 value above 0,90 for both alternatives. It is indicative of a high and reliable value for both cases, confirming the relationship that as higher the time the crop lives together with weeds, the plant height variable goes down during the early development period.

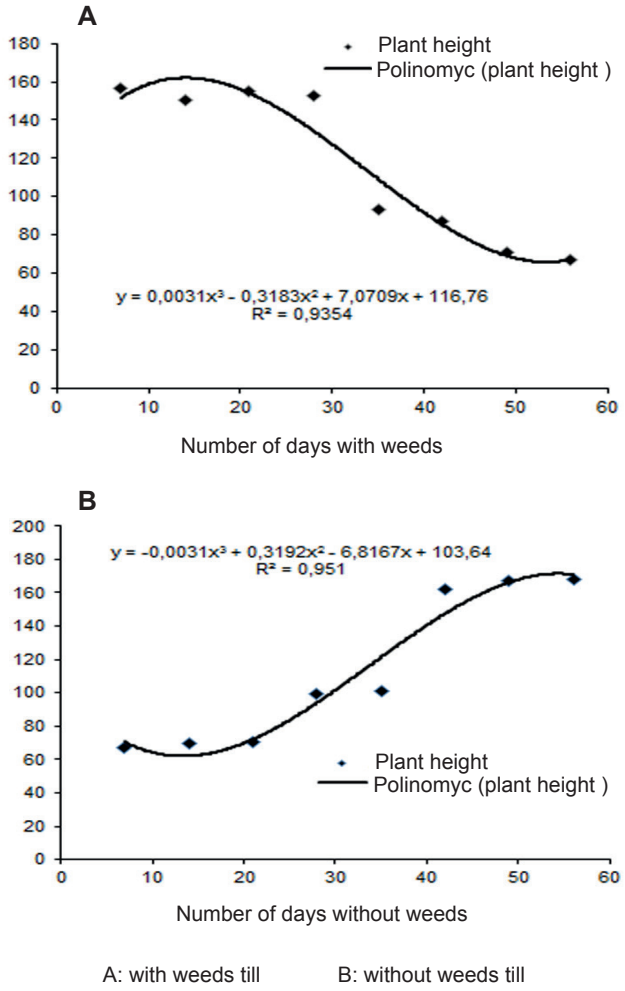


Figure 1. Plant height relationship (h) regarding the number of days with weeds

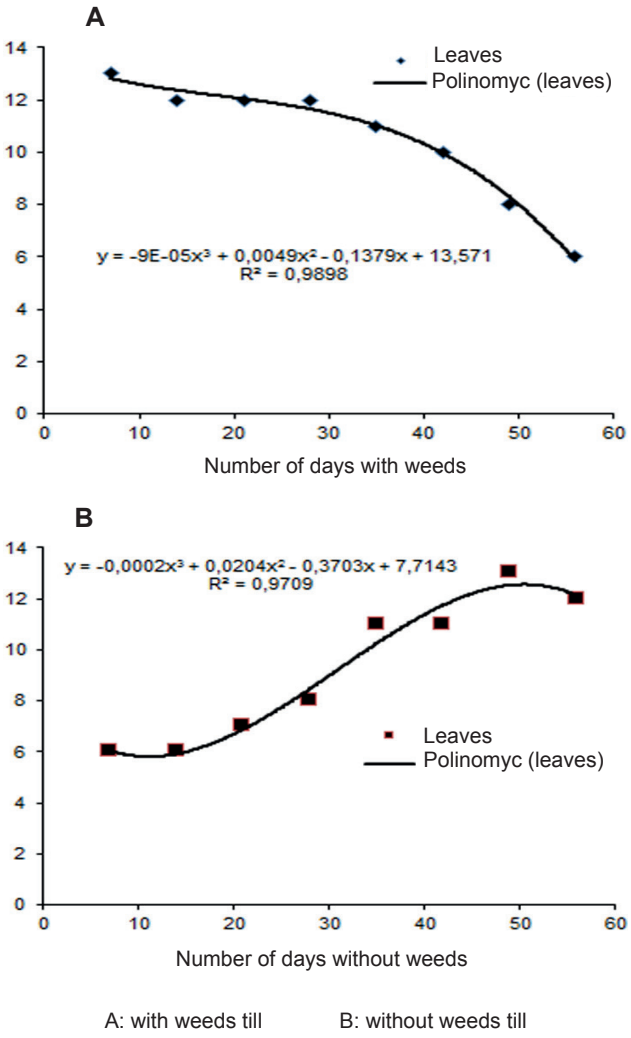


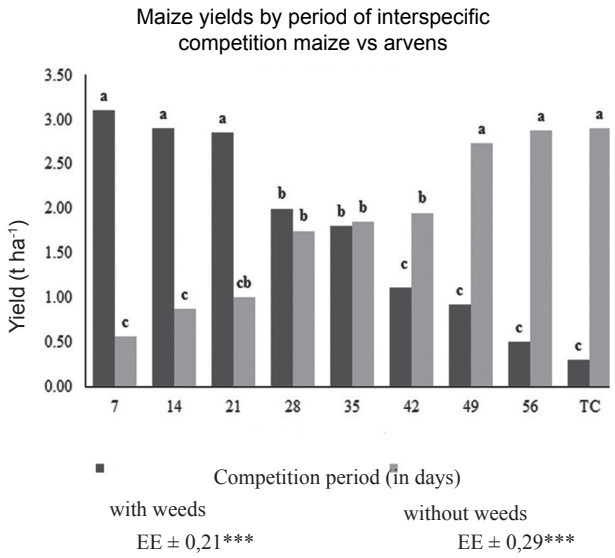
Figure 2. Number of leaves relationship (nh) regarding the number of days

The analysis of the number of leaves showed a similar behavior by having an R^2 value close to 0.95 for the alternative "*With management till"* which provides a somewhat higher correlation than the one shown by the alternative "*Without management till"* that did not reach the value of R^2 0.90 though equally efficient. This result shows a close relationship between the number of totally expanded leaves and yields. Similar results were found in potato (12) indicating that leaves regulate the photosynthetic capacity of the crop assuring the function of feedback among plants and their light regime.

As weeds live longer with the crop, interspecific competition is faster, but this damaging effect is insignificant in the first three weeks, then the process is accelerated, showing up faster after the third week which supposes that the critical period between corn and weeds comes in from the third to the fourth week.

Yield analysis

Final yields reached in this research clearly showed the period considered as critical (Figure 3).



Equal letters are equivalent to non significant differences P≤0,001 according to Duncan (1955).
Numbers indicate periods of weed management
TC: With and without management of weeds during the whole cycle

Figure 3. Corn yields (t ha^{-1}) with and without weeds till 56 days with two controls (TC1 y TC2) without and with wedds respectively, throughout the whole cycle (Season 2011-2012)

The damaging effects over the crop (without weeds till), were ascending up to a point in which they stabilized, as if plants would be already prepared from the physiological point of view, to withstand any attacker regardless how damaging it could be. This variety seems to reach this point after six weeks, that is, between 42 and 49 days after germination, coinciding with the presence of ten leaves per plant and an average height of 120 cm.

It is very important to point out that though weeds are responsible of affecting yields, they also seem to stimulate crop growth in the first and second growth week, probably for the competition established for light and other growth factors; however, the damage is considerable, from coming weeks on (before and during the determined critical period), so it is assumed as very important to avoid the interspecific coexistence during the critical period. This analysis leads to a warning on numeric values of the treatments kept clean since early weeks, compared to those that will be cleaned after the second week.

According to other research works, the field should be clean until the crop covers the whole planted area, and from that moment on, emerging weeds will have less influence on the expected production (13). But the most important and vital is to make optimum space arrangements that close the path of light towards weeds so that the agricultural space be used by corn plants in favor of the productive system (1).

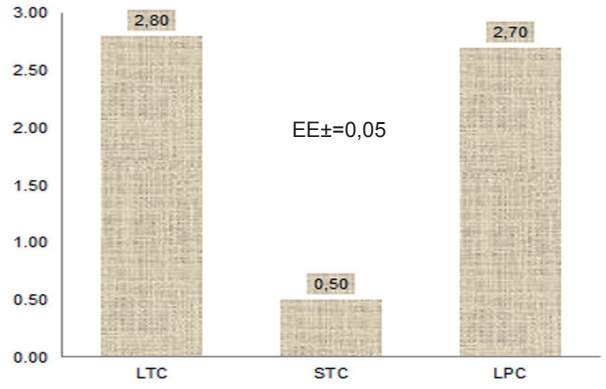
Special attention deserves the danger that uncertain natural conditions caused by climate change pose for tropical crops through hindering management practices. A carelessness or impossibility of managing weeds before the critical period, could later on become a non-controlled damage; a reason that would advise assuming the principle that with weeds till the second week and without weeds one week before the determined critical period. Research done with a more practical sense, recommended to manage weeds in corn during the early third of their cycle[F].

There were higher yield levels in plots with weeds till 7, 14, 21, days than, without weeds after the critical period. Plots without weed management after the critical period showed lower yields (below 1 t ha^{-1}) with an average weight of 140,9 g per cob, and a maximum of 1,8 t ha^{-1}. In this regard, there are evidences assuring that average yields as to total weight of the ear, are from 144 to 470 g (14); any yield below these levels show a negative and significant influence of certain concurrent factors to yield reduction.

Critical period analysis under Chianga's conditions

Once the critical competition period was known in Ngongoinga, the trial conducted in Chianga would allow to confirm the results (Figure 4).

[F] ACMG. *Agrónomos del centro maya generación 2010-2014. Alelopatía. Sustentabilidad. La base del futuro* [en línea], 2010, [Consultado: 30 de abril de 2014], Disponible en: <http://agronomia1ersemestreunach.bloogspot.com/2010/09/alelopatia.html>.



where:
LTC- with weed management throughout the cycle;
STC- without weed management throughout the cycle;
LPC- with weed management only in the critical period
Equal letters indicate non significant differences P≤0,001 according to Duncan (1955).

Figure 4. Corn yields (t ha^{-1}). Season 2013-2014

Coinciding with the slow damage and little pronounced effect of the first three weeks it was possible to state that, like in the first trial, weed management between the third and fourth week and until the seventh one, means to maintain the crop weed-free throughout the cycle. The results corroborated the previous response by not finding significant differences among clean treatments throughout the cycle *vs* clean treatments during the critical period. It was proven that the field could be maintained weed-clean only in this period, which is coincident with those who defend the execution of cultural practices before and after the so-called critical period, with the consequent increase of energetic expenses and unbalance of the agroecosystem (15).

Though in a similar research in Cuba with short-cycle varieties, the competition period between weeds and corn ocurred from 24 to 40 days after crop germination (14) and in other trials the corn critical period ocurred from 28 to 45 days after germination[G] (3); for this trial, the competition period between weeds and corn ocurred from 21 to 49 days, so the critical point showed up 35 days after germination.

[G] Departamento de agronomía, Universidad Nacional del Sur. *Identificación de algunas plántulas de malezas de la región de Bahía Blanca* [en línea], 2005, [Consultado: 1 de noviembre de 2005], Disponible en: <http://www.criba.edu.ar/agronomía /técnicas/malezas/introd.htm>.

CONCLUSIONS

- The excessive use of herbicides in corn under single crop conditions, has caused the establishment of species with a high presence like *Cyperus rotundus,* L., whose management with chemicals is not effective and non-ecological.
- Where crop rotation is practiced, weed cenosis with interspecific competition with corn is more abundant and diverse, many of them are useful as food, medicines or both.
- Both the height of corn plants and the number of leaves are variables correlated with weeds management period and crop yield, so they can be used as references to predict yields according to the time of interspecific contact and also the final yields of the crop.
- The critical period of corn (long-cycle variety) and weeds started between the third and fourth week and finished on the seventh week, that is, from 21 to 49 days after germination. The critical point was recorded 35 days after germination.

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